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11. SUPPLEMENTARY NOTES

13. ABSTRACT (Maximum 200 words)
The goal of this research is the development of a generic agent architecture to support the development of large-scale distributed realtime situation assessment systems (DSA). The key issues are how to organize both local agent and network-wide problem solving so that the agents can cooperate effectively to produce answers of appropriate quality within fixed deadlines, using limited communication bandwidth, and having performance degrade gracefully as sensors, communication links, and processors fail. The basis of our generic agent architecture is the use of the TAEMS task structure representation. This domain-independent representation permits a problem solver to express 1) its perceived medium timeframe goals; 2) alternative methods for achieving these goals and the trade-offs among them (in terms of expected quality of results and duration); 3) how the solutions to subgoals contribute to the overall goal; and 4) the relationships among the tasks needed to achieve specific goals. The relationships among different agents' task structures are used in implementing domain-independent coordination protocols. The agents' local coordination modules interact, resulting in modifications to teh agents' local task structures. The adapted local task structures are used by each local realtime scheduler to find the best sequences of activities to meet the network-wide objectives.

14. SUBJECT TERMS
distributed situation assessment; coordination; multiagent systems; real-time AI; interpretation.

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1. ADMINISTRATIVE INFORMATION

a. Title: Distributed Real-Time Situation Assessment

b. Organization: University of Massachusetts/Amherst

c. Subcontractors: None

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f. Numerical Productivity Measures:

Refereed papers submitted but not yet published: 5
Refereed papers published: 2
Unrefereed reports and articles: 1
Books or parts thereof submitted but not yet published: 0
Books or parts thereof published: 0
Patents filed but not yet granted: 0
Patents granted: 0
Invited Presentations: 3
Contributed Presentations: 4
Honors Received: 0
Prizes or Awards Received: 0
Promotions obtained: 3 PhDs
Graduate Students Supported: 3
Post-docs supported: 1
Minorities supported: 0

2. PROJECT SUMMARY

The goal of this research is the development of a generic agent architecture to support the development of large-scale distributed real-time situation assessment systems (DSA). The development of such systems holds much promise for a variety of military and commercial applications. Examples of such applications include: distributed sensor networks, situation assessment in a wireless and mobile battlefield, distributed network diagnosis, cooperative information gathering, distributed perceptual processing for cooperating robots/autonomous vehicles, and computer-supported cooperative work on situation analysis tasks. DSA will also be an integral component of many distributed planning and scheduling systems.

We see the key issues as being how to organize both local agent and network-wide problem solving so that the agents can cooperate effectively to produce answers of appropriate quality within fixed deadlines, using limited communication bandwidth, and having their performance degrade gracefully as sensors, communication links, and processors fail. An equally important issue is how to put these complex systems on a more theoretically sound basis. For instance, can we statistically characterize the performance of the system as a whole given the characteristics of local agent performance. Other important issues concern how to scale up distributed assessment systems to tens and perhaps hundreds of agents and how to embed the DSA in a larger system, such as one that involves planning and scheduling.

The basis of our generic agent architecture is the use of the TAEMS task structure representation. This domain-independent representation permits a problem solver to express: (1) its perceived short to medium time frame goals; (2) alternative methods for achieving these goals and the trade-offs among them (in terms of expected quality of results and duration, and the likelihood of achieving these characteristics); (3) how the solutions to particular subgoals contribute to the overall goal; and (4) the relationships among the tasks needed to achieve specific goals (both intra-agent relationships and inter-agent interactions). The relationships among different agents' task structures are used in implementing domain-independent coordination protocols. The agents' local coordination modules interact, resulting in modifications to the agents' local task structures. The adapted local task structures are then used by each local real-time scheduler to find the best sequences of activities to meet the network-wide objectives.

To evaluate this generic agent architecture, we have been using the DRESUN interpretation system, a sophisticated knowledge-based situation assessment problem solver. This system was chosen because our earlier research suggested that sophisticated, self-aware agents were required to support the flexible and dynamic problem-solving strategies that are necessary in complex DSA tasks. DRESUN supports the communication and use of incomplete information and information at multiple levels of abstraction, and explicit reasoning about the

interrelationships of evidence in different agents. We have also implemented an abstract but quite realistic distributed vehicle monitoring application that incorporates such phenomenon as ghosting and vehicles moving in patterns in order to be able to test the effectiveness of our proposed agent architecture.

A major focus of this first year has been to complete the design and begin the implementation of our agent architecture. As part of this effort we have significantly increased the capabilities of our design-to-time real-time local scheduler. The real-time scheduler had to be modified to handle uncertainties about the type and strength of task relations, and more complex quality accumulation functions that are representative of interpretation problem solving. We have also embarked on a reimplementation of the scheduler in C++ to improve its performance. We also needed to extend the DRESUN architecture to be able to generate TAEMS task structures to represent its current and future activities. This involved changing the reactive control architecture of DRESUN to be more reflective. We changed it to (1) develop abstract (TAEMS) models of its future tasks; (2) drive its activities from these tasks (by way of the scheduler); and (3) provide for meta-tasks that can selectively refine these descriptions as needed for effective scheduling. In the process, we also recognized the need to introduce a more complicated version of task relationships in order to provide the appropriate information to the coordination module to make decisions about the level of detail of information that was appropriate to communicate among agents. Finally, we made important strides in developing formal models that describe the expected result of the communication protocols among agents. These theoretical results have led us to understand the limitations of our existing protocols and provided insights in how to improve them.

3. WORK PLANNED FOR NEXT YEAR

The focus of the next year will be on completing the implementation of the agent architecture and its full integration with the DRESUN problem-solving system. We plan the extensive testing/evaluation of the agent architecture in the setting of the distributed vehicle monitoring application. As part of this effort, we will need to develop new coordination protocols to make decisions about the level of detail at which information needs to be transmitted among the agents. We also expect to develop new network termination protocols that can provide higher quality solutions, and understand from a theoretical basis how the quality of local decision making affects the overall quality of network problem solving. In this context, we will begin to investigate scaling issues and degradation issues caused by sensor, communication and processor failures.

4. TECHNICAL TRANSITIONS

Boeing Helicopter, as part of an ARPA contract under the MADE program, is planning on using our agent architecture for coordination of concurrent engineering activities.

5. MOST SIGNIFICANT ACCOMPLISHMENTS OF PAST YEAR

- The use by Boeing Helicopter of the agent architecture for coordination of concurrent engineering activities

- The development of the concept of near monotonicity as a way of explaining performance of distributed interpretation systems

- The development of a real-time scheduler that takes into account cost and uncertainty in specifications of task quality and duration

6. PUBLICATIONS

Carver, N. and Lesser, V. "A Formal Analysis of Solution Quality in FA/C Distributed Sensor Interpretation Systems." To appear in *Proceedings of the Second International Conference on Multi-Agent Systems* (ICMAS-96), Japan, 1996.

Carver, N. and Lesser, V. "Nearly Monotonic Problems: A Key to Effective FA/C Distributed Sensor Interpretation?" *Proceedings of Thirteenth National Conference on Artificial Intelligence*, Portland, Oregon, 1996.

Garvey, A. and Lesser, V. "Issues in Design-to-time Real-time Scheduling." To appear in AAAI Fall Symposium Series on Flexible Computation, Boston, November 1996.

Garvey, A. and Lesser, V. "Design-to-Time Scheduling and Anytime Algorithms." To appear in *SIGART Bulletin*, 1996.

Nagendra Prasad, M.V., Decker, K., Garvey, A. and Lesser, V. "Exploring Organizational Designs with TAEMS: A Case Study of Distributed Data Processing." To appear in *Proceedings of the Second International Conference on Multi-Agent Systems* (ICMAS-96), Japan, 1996.

Nagendra Prasad, M.V., Lesser, V. and Lander, S. "Retrieval and Reasoning in Distributed Case Bases." In *Journal of Visual Communication and Image Representation, Special Issue on Digital Libraries*, Vol. 7, No. 1, pp. 74-87, March 1996.

Oates, T., Nagendra Prasad, M. and Lesser, V. "Cooperative Information Gathering: A Distributed Problem Solving Approach." To appear in *Software Engineering Journal*, 1997.

Wagner, T. "Towards an Empirical Model of WWW Site Response Times." University of Massachusetts Department of Computer Science Technical Report 96-19, March 1996.

7. ON-LINE INFORMATION

A fairly comprehensive list of research papers from my group is contained at http://dis.cs.umass.edu/. The research topics under the titles "A Framework for the Analysis of Sophisticated Control," "Formal Analysis of the FA/C Distributed Problem-Solving Paradigm," "Generic Architecture for Real-Time Distributed Situation Assessment," "The DRESUN Testbed For Distributed Situation Assessment" and "Design-to-time Real-time Scheduling" contain most of the papers relevant to this contract.

8. Visuals/Slides

(Submitted as separate attachment.)

Main goal: Development of a generic agent architecture for large-scale, distributed real-time situation assessment

- Layered agent architecture
  - R/T scheduler, sophisticated SA agent, and coordination module

- Integration of components via TAEMS
  - domain-independent representation of tasks, with their characteristics and interrelationships

- Empirical evaluation of large-scale DSA systems in DSA testbed

- Formal analysis of the performance of DSA systems and coordination protocols.
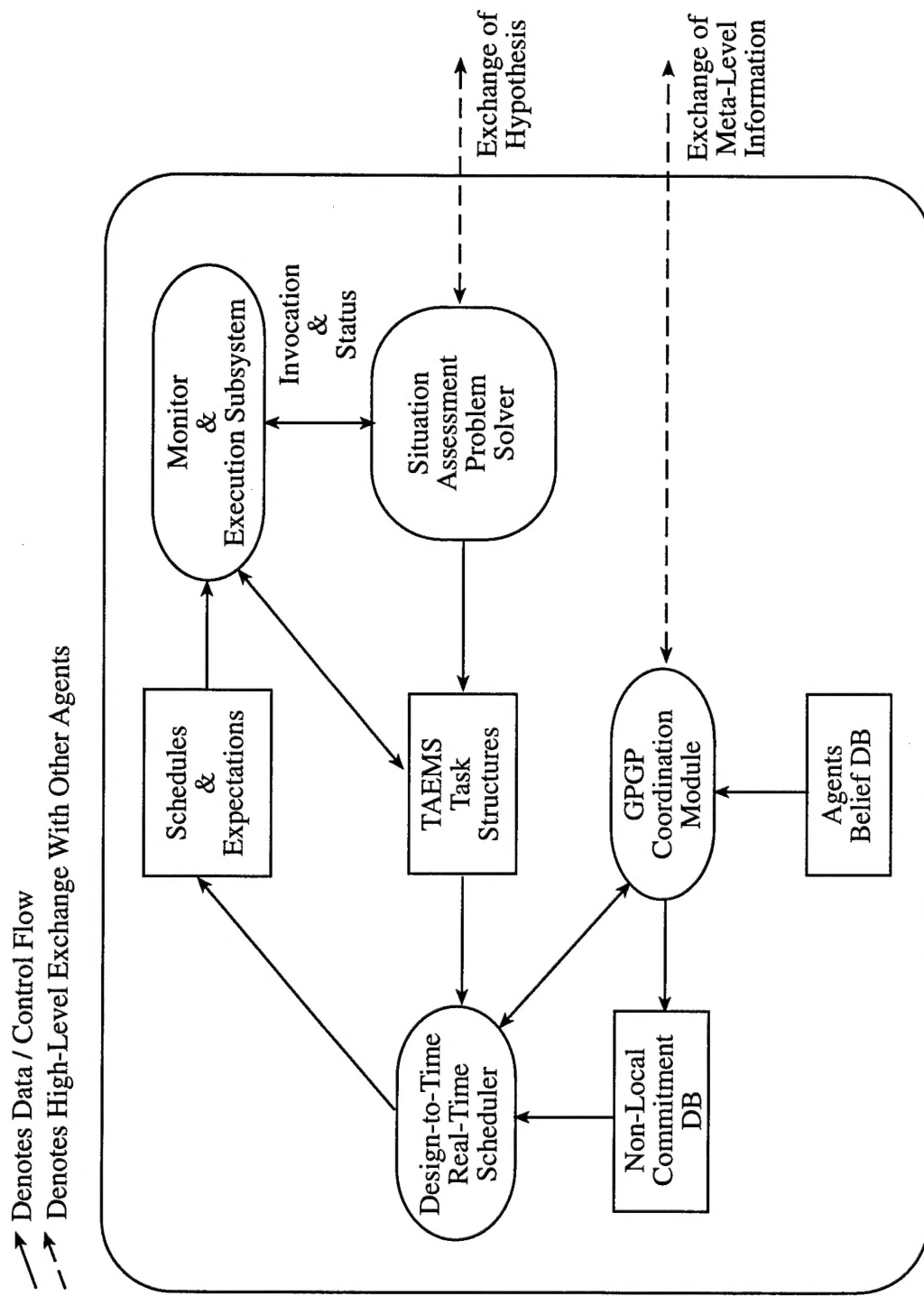
Distributed Situation Assessment (DSA): Integral Part of the Battlefield of the Future

Situation Assesment Agents Cooperating to construct a Coherent and Appropriate Tactical Picture

- Why Now: Ever increasing availability of on-line information sources, mobile and wireless communication, advanced sensors, software to support agents

- Key Challenge: Development of appropriate, generic agents that can be used to speed up the development of real-world DSA systems

  – agents need to reason about appropriate trade-offs among solution quality, time to produce results, and cost, when selecting and processing information

  – agents need cooperation protocols that scale, adapt to changing network environment, predictable levels of performance

PROJECT MILESTONES

- 1/97 Integrate GPGP coordination module into testbed.

- 5/97 Validate agent architecture on complex, R/T DSA scenarios.

- 9/97 Develop coordination algorithms appropriate for large DSA systems,

- 1/98 Develop coordination algorithms to facilitate graceful degradation

- 3/98 Extend the layered agent architecture to handle the embedding of DSA systems

- 6/98 Extend the layered architecture to incorporate a learning module.

Agent Architecture for Real-Time Distributed Situation Assessment

Monitor & Execution Subsystem

Invocation & Status

Situation Assessment Problem Solver

Exchange of Hypothesis

Schedules & Expectations

TAEMS Task Structures

GPGP Coordination Module

Exchange of Meta-Level Information

Agents Belief DB

Design-to-Time Real-Time Scheduler

Non-Local Commitment DB

Denotes Data / Control Flow

Denotes High-Level Exchange With Other Agents